

OPERABILITY ENGINEERING IN THE DEEP SPACE NETWORK

Belinda Wilkinson

N 9 4 - 2 3 9 3 0

Jet Propulsion Laboratory, California Institute of Technology
Pasadena, California/USA

ABSTRACT

Many operability problems exist at the three Deep Space Communications Complexes (DSCC's) of the Deep Space Network (DSN). Four years ago, the position of DSN Operability Engineer was created to provide the opportunity for someone to take a system-level approach to solving these problems. Since that time, a process has been developed for establishing communication between operations personnel and development engineers and for enforcing user interface standards in software designed for the DSCC's. Plans are for the participation of operations personnel in the product life-cycle to expand in the future.

Key Words: operability, communication, standards, documentation, user interface

1. BACKGROUND

The Deep Space Network (DSN) is a space-to-ground telecommunications network operated by the Jet Propulsion Laboratory (JPL) for NASA. It is used for supporting deep-space missions, high Earth-orbiting flight projects, and radio astronomy experiments. It consists of multiple facilities, including a central Network Operations Control Center (NOCC) at JPL, the Central Communications Terminal (CCT) at JPL, and three Deep Space Communications Complexes (DSCC's), located in Goldstone, California; Madrid, Spain; and Canberra, Australia.

There are many people within the JPL community with a legitimate interest in the requirements, design, and implementation of DSN subsystems. Since JPL has a matrix management organizational structure consisting of program offices and technical divisions, the responsibilities for different phases of the product life-cycle cut across organizational boundaries. Also, since DSN operations facilities are worldwide, there are

several different organizations in different physical locations that are part of the operations structure. Communication problems can develop as a result of this distribution of personnel across organizational boundaries and over many physical locations.

Four years ago, the DSN created the position of the DSN Operability Engineer, with the charter to ease the operational complexity of the network. This position requires someone with a background in both software engineering and human factors engineering, as well as considerable management experience.

This paper describes the process that has taken place since I was appointed to the position of the DSN Operability Engineer.

2. OPERATOR POINT-OF-VIEW

One of the first steps I took after receiving the new assignment was to visit the DSCC sites in California, Spain, and Australia. This provided me an opportunity to meet operations personnel and learn about their concerns and problems. I spent considerable time observing day-to-day operations and talking with operators. Other JPL engineers had done this, but as one DSCC operator later commented, "That was the first time that someone actually wrote down the comments that we made." In general, operators felt that developers never listened to them and never incorporated solutions to their complaints in new software releases. It was also the operators' perception that the DSN is a collection of independent subsystems rather than a cohesive system.

Actually, developers at JPL were very aware that operators were not happy, but did not always understand the specific areas of concern or have the expertise to solve the problems. Even when problems were understood, no one before had ever had the responsibility to collect the comments and provide a system-level approach to responding to them. That was the service that I could perform.

3. THE PROBLEM DEFINED

Many operability problems were discovered during these discussions with operators. As an example, at the DSCC's there are over 1500 commands that the operator must use to control the system. Since the current Monitor and Control subsystem only provides a command-line interface, the operator must memorize the 1500 commands. Many of the commands, particularly in the area of subsystem configuration, are not necessary, since the appropriate information could be accessed by the software from files. Another problem is that similar functions in different subsystems are often initiated by different commands: for example, the command to perform subsystem configuration is variously CNF, CONF, or CFG. These problems have developed because within each operational site are numerous subsystems that were designed, developed, and upgraded at different points in time. Traditionally, there has been little communication among the engineers responsible for developing the various subsystems; thus, a set of subsystems has been created that is not always cohesive in the operational environment.

There were many other operability problems. Owing to insufficient automation, information was frequently communicated on pieces of paper, thus requiring extensive key-in's on the part of the operator. The displays used for monitoring the status of the DSN were far too crowded, and the out-of-date technology prohibited true hierarchies of displays. Log displays were congested with too many messages, thus causing important messages to be lost in the heavy flow of traffic. The monitor and control equipment was antiquated, and monitors were poorly placed from an ergonomic point of view. Some of the monitors were so old that the clarity of the display presented was very poor, causing difficulty in reading the data.

Another operability problem was the lack of common displays and acronyms among the operational facilities: the DSCC's, the NOCC, and the CCT. The operators at the facilities are constantly in voice communication, and difficulties arise because of a lack of standards in presenting information (e.g., the unit of measure for a particular data item). This problem extends beyond the DSN boundaries to the DSN interface with the Multi-mission Ground Data System (MGDS) in the JPL Space Flight Operations Facility, from which another version of the data may be given to an operator.

4. COMMUNICATION

Three years ago, several major tasks were starting up that were designed to enhance the DSCC's with the delivery of many upgraded subsystems. One goal of these tasks was to improve the operability of these subsystems, although many of the operability problems cannot be resolved until a new Monitor and Control subsystem is provided. Although the Monitor and Control subsystem was not scheduled for replacement, the operability goal was set to eliminate as many problems as possible.

One major goal I had was to increase the level of communication between the operations personnel at the DSCC's and the development engineers at JPL. At that time, no formal mechanism existed for communication, and any communication that occurred did so on an ad hoc basis. Attempts at effective communication were made by using such techniques as videoconferences, overseas phone calls, and operability meetings at JPL. Pivotal in the success that was achieved was the appointment of a person at each DSCC to serve as the Operability Interface Engineer for that DSCC. That person is responsible for talking with the various DSCC crews and compiling the operator input into one integrated viewpoint for that DSCC.

The forum for communication that has proven to be the most successful is to send information electronically and then to have follow-up telephone conferences as needed. The major problem with this method of communication is one of time constraints. The personnel at the DSCC's are very busy and cannot always read and critique a document immediately upon receiving it. Of course, the JPL development engineers generally need to have answers very quickly if they are to remain on schedule. We have not solved the resulting conflict effectively.

Early on, videoconferences were tried, but these did not prove to be very successful forums for communication. The data rates of the video-conference system we used were so low that all viewgraphs had to be sent ahead of time. Since it took several minutes to paint a screen, sending anything in real time was not practical. Although time zone differences exist, from California to Australia to Spain, these differences were not a major problem since the involved people showed a willingness to come in during the night, if necessary, in order to participate.

Face-to-face communication with representatives from the DSCC's has been possible because, as part of the tasks, each DSCC provides one person to work at JPL as part of an Independent Test Group (ITG). Operability meetings have been held with the ITG members and JPL development engineers participating. These groups have been very useful, but are limited in their decision-making ability in that the ITG member is not always the Operability Interface Engineer for that DSCC and thus may not be able to speak officially for the DSCC.

In alternate years, the Operability Interface Engineers from the DSCC's come to Pasadena for an Operability/Monitor and Control workshop that generally lasts for one week. The topics discussed are quite varied, from anomalies in the current subsystems to creative thinking concerning the future. These meetings have been very useful in providing an opportunity to exchange ideas and make decisions.

5. DOCUMENTATION

Another opportunity to improve operability was to enforce the rule to design and document the user interface early in the design process, rather than to allow the development engineers to design the user interface during implementation and to document whatever user interface was delivered. This was accomplished by holding a series of rigorous reviews of the software operators manuals with the participation of operations personnel during the time frame of the high-level design. The challenge here is to follow through and make sure that the development team does not change the interface during implementation. The ITG team members test for this as part of their function.

Although user interface standards already existed in the DSN, the standards had never been successfully enforced. Enforcement has now been accomplished via the early review of the software operators manuals by operations personnel and the signature approval of the manuals by the Operability Engineer. The early review of the manuals has also increased the usability of the subsystems.

To improve the usability of documentation for operations personnel, a new format for the software operators manuals was developed with the participation of the users. The new format is designed to present an efficient, real-time

document, with certain sections designed for quick reference and other sections for more detailed study. A section on messages and suggested operator responses is included. The manuals are in a landscape format, so that a picture of a display and the written description of that display are available on back-to-front pages for easy viewing. Since work space at the operator consoles is limited, the manuals are currently in the process of being printed on smaller (8.5 inches by 5.5 inches) paper. They will be put in binders for ease of use. Also, a quick-reference manual containing information on all subsystems is being developed.

6. SUCCESSES AND FAILURES

One evidence of success is that development engineers are more conscious of operability issues these days. They hold meetings on the issues, ask questions, and find they are rewarded by talking with operations personnel. In general, there is a heightened awareness of operability issues. The following is a description of some of the specific successes and failures.

There is far more communication these days between operations personnel and JPL engineers. Currently, a proposal is being developed that will formalize the methodology for the participation of operations personnel in the entire development life-cycle of all subsystems in the DSN, from requirements through implementation. We have evolved from almost no participation four years ago, to participation in the design phase, to participation in all phases.

An operability module has been written for the DSN baseline requirements document that will govern all new subsystems. A preliminary requirements document for a new Monitor and Control subsystem at the DSCC's is being reviewed. This document contains many requirements designed to remove operational complexity from the DSCC's.

Other successes include a set of standard commands and display acronyms, online help screens, and standard system-administration procedures. New subsystems provide for configuration with one command by having the software access parameters from files sent electronically from JPL, rather than requiring the operator always to enter the parameters manually. Also, operations personnel were allowed to participate early enough in the

design process that frequently their input was incorporated into the final products. When the design could not accommodate their input, at least the operators were able to understand the reasons and learn the period of time when the product would not have the feature(s) they wanted.

The new subsystems use a common software program set providing standardization of many user interface features. Since the code is being written by one group, standardization is assured.

In the Monitor and Control subsystem, operations personnel have contributed very instrumentally to the requirements for the various releases. Operators had long been unhappy with the position of one of the four monitors found on each operator workstation. Discussions were held with the DSCC's, and all new workstations have the monitor positioned in a more ergonomically favorable location. Also, the worst monitors have been replaced with newer ones to improve readability.

The major failure, so far, involved one particular subsystem. Even though the subsystem development team talked extensively with the personnel at one DSCC, they did not write a software operator manual early in the design process and did not implement features agreed to in the meetings. Very few operability items were incorporated in the first release of that subsystem, but subsequent releases are addressing the items that were asked for by the DSCC personnel.

7. FUTURE

There are still major improvements to be made.

The following items are the ones to be implemented over the next couple of years.

In order for operations personnel to evaluate proposed designs, an operations scenario needs to be developed for each subsystem and activity, starting at requirements generation and being further refined at each stage in the development life-cycle. A standard for this operations scenario needs to be developed.

A more extensive data base of acronyms and units of measure needs to be developed to be used throughout the DSN--from the DSCC's, to the CCT, to the NOCC. Common displays need to be developed for utilization by all DSN facilities and by the Multimission Ground Data System in the JPL Space Flight Operations Facility.

New standards must be developed for graphical user interfaces, and a user interface presentation must be developed that allows the DSN subsystems to be viewed as a system by the operator, and not just as an ad hoc collection of program sets.

With all of these changes, the DSN will be able to continue doing an excellent job of tracking and data acquisition, and the operational environment will continue to be improved for the DSN operators.

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